

**California Department of Transportation
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**Berm and Wall Options, Coding of Low Barriers, Zero Height
Index, Grade Corrections, and Other Issues in
Sound32/ Sound 2000 and LeqV2 Traffic Noise Prediction
Programs**

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Berm and Wall Options, Coding of Low Barriers, Zero Height Index, Grade Corrections, and Other Issues in Sound32/ Sound 2000 and LeqV2 Traffic Noise Prediction Programs

Introduction

Caltrans currently uses two traffic noise prediction programs, Sound32 in DOS or Sound 2000 in Windows®, and LeqV2, and will continue to do so until the new FHWA Traffic Noise Model® (TNM) is adopted by Caltrans and mandated by the FHWA. Currently, this is anticipated to occur in December 2002.

Sound32 and LeqV2 have been in use since the early 1980's for future traffic noise impact analyses and the acoustical design of noise barriers. Sound32 (Sound 2000) is a Caltrans version of the pre-TNM FHWA noise models Stamina2.0/Optima. LeqV2 is a simplified model based on the manual method presented in FHWA-RD-77-108 report titled Highway Traffic Noise Prediction Model (108 report). Both models are based on the theory in the 108 report, with Caltrans-specific vehicle noise reference energy mean emission levels (Calveno Remels). During the twenty years the models have been around, there have at times been concerns and confusion about the coding of several options in the models. The noise analyst must use good engineering judgment when using the noise models. This requires understanding of how the various options affect model results.

This technical advisory discusses the problems and recommendations concerning issues that at times have caused erroneous or confusing model results, specifically:

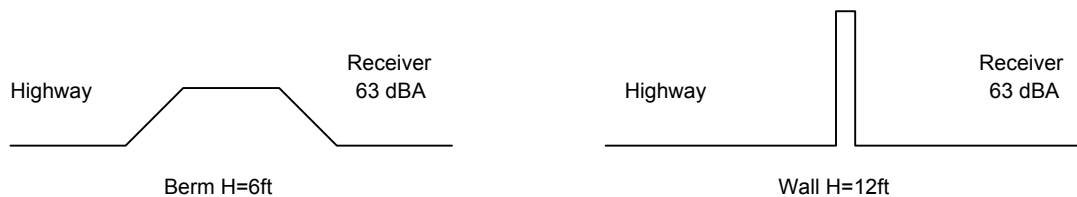
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Use of Earth Berm vs. Wall Option

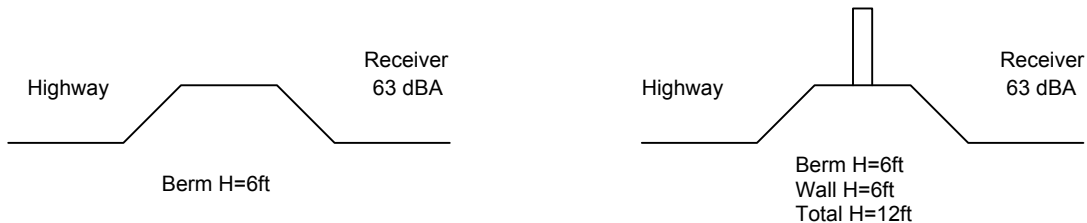
Problems. Both Sound32 (Sound 2000) and LeqV2 programs have the option of coding noise barriers as earth berms, or as walls. According to these programs earth berms provide a 3-dBA greater attenuation than

walls in the shadow zone. This may prompt the noise analyst to evaluate trade-offs between higher walls and lower berms. Depending on the site geometry, the programs can predict same barrier attenuations for a 12-foot wall and a 6-foot berm (Figure 1a). Furthermore, placing a wall on top of a berm destroys the benefit of the berm according to the prediction models. Thus it is possible that the predicted barrier attenuation for a 6-foot wall on top of a 6-foot berm is the same as for the 6-foot berm by itself (see Figure 1b). In reality, this has never been demonstrated with measurements.

Figure 1- LeqV2 and Sound32 (Sound 2000) Berm vs. Wall Option



a. Example – Predicted: 6 ft high berm provides same attenuation as a 12 ft high wall



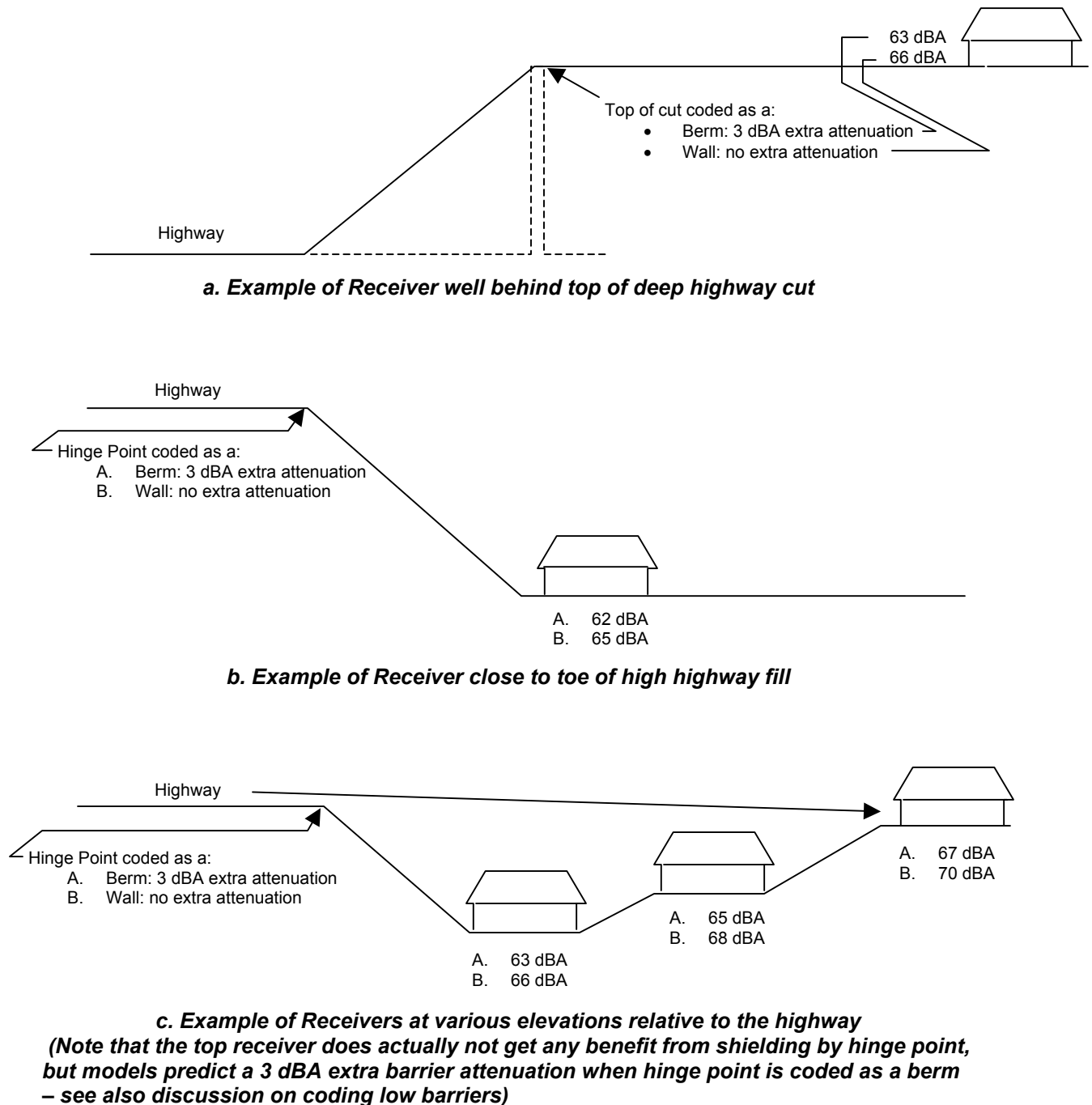
b. Example – Predicted: 6 ft berm provides same attenuation as a 6 ft wall on top of a 6 ft berm

Studies have shown that berms generally provide an extra 1–3 dBA of attenuation (FHWA-EP-00-005/DOT-VNTSC-FHWA-00-01, titled FHWA Highway Noise Barrier Design Handbook, Final Report, February 2000).

Using both the berm and wall options in Sound32 (Sound 2000) and LeqV2 can therefore lead to inconsistencies in barrier attenuation, when berms and walls are evaluated. A 1981 Caltrans/FHWA research project presented anecdotal data that the 3 dBA extra attenuation may be applied to tops of deep cuts of 24 feet coded as berms for receivers 50 feet or more behind the top of cut. (Figure 2a) (FHWA/CA/TL-81/07, titled Evaluation of Noise Barriers, June 1981). There is also reason to believe that the same is true for highways on high fills. Thus the hinge point of the fill may provide up to 3 dBA extra attenuation for receivers

close to the toe of the fill (Figure 2b). For the case where the receivers are close to the same elevation of the highway, the hinge point coded as a berm may cause over predictions of “barrier” attenuations (Figure 2c) (see also following discussion of coding low noise barriers).

Figure 2 – Coding Tops of Cuts and Hinge Points as Berms or Walls



For berms designed specifically for noise abatement, as shown in Figure 1, the extra attenuation has not been confirmed. The extra attenuation has also not been confirmed for cases where noise paths are close to grazing the hinge point of a highway in fill (i.e. receivers that are close to the same elevation of the highway) (Figure 2 c). Although very few full-scale research projects with real traffic have been conducted, noise analysts generally believe that berms of the same height as walls provide only 0-2 dBA more attenuation than walls, based on anecdotal data.

Recommendations. HQ Noise, Air, and Hazardous Waste Management Office recommends not to use the berm option (use wall option instead), unless it can be shown that the 3 dBA extra attenuation exists, through model calibration measurements behind existing tops of cuts, hinge points or berms. The use of the berm option for future berms is never recommended. In Sound32 (Sound 2000) the wall options are: masonry, masonry on Jersey barrier, and concrete. The use of any of these three wall options will yield the same acoustical results.

In LeqV2 the hinge point should not be coded as *height of shoulder*, but instead as a *barrier height* of zero, and *barrier type* zero (wall). Further caveats are discussed in the following section covering *Coding of Low Barriers*.

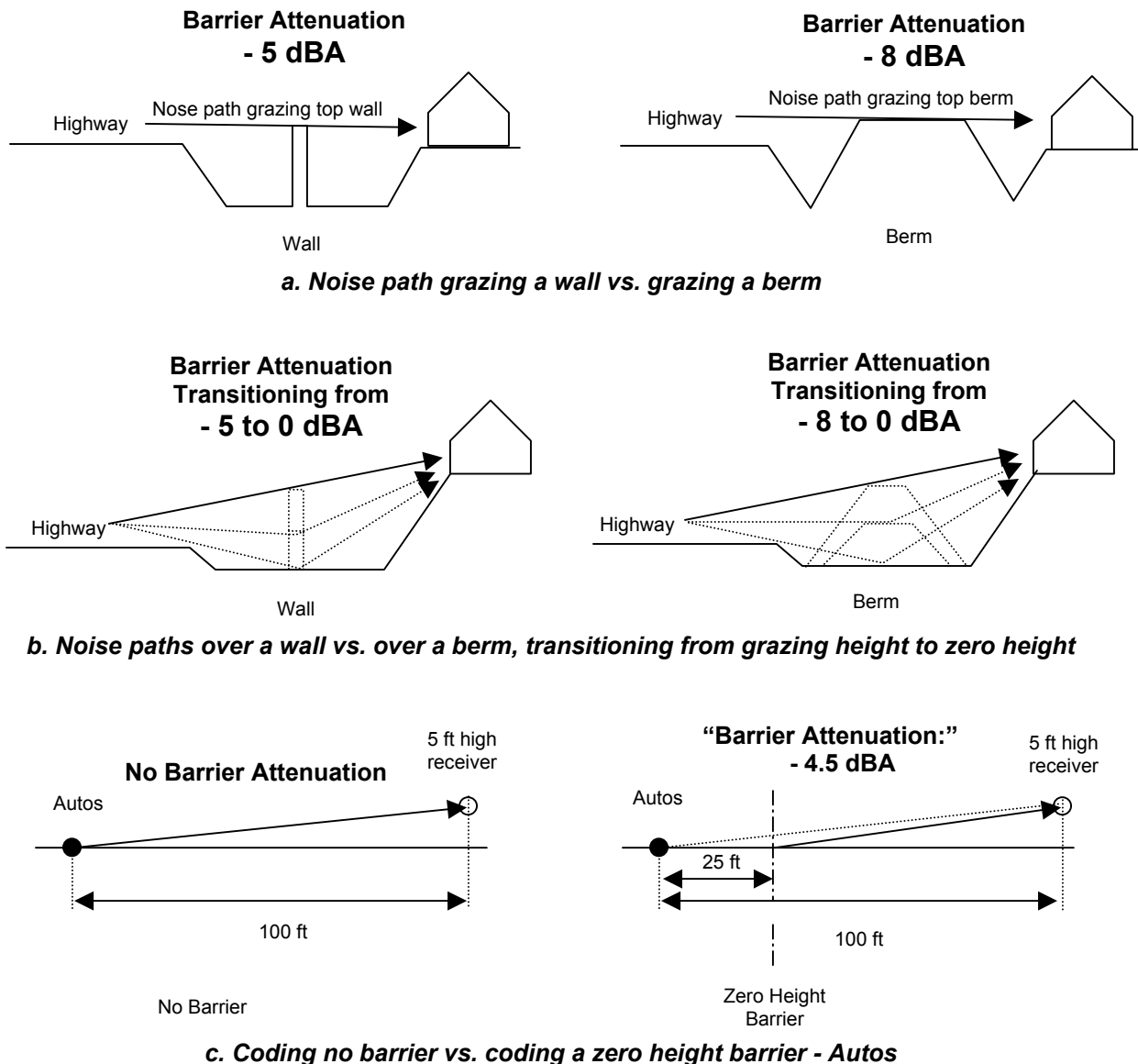
Coding Low Noise Barriers

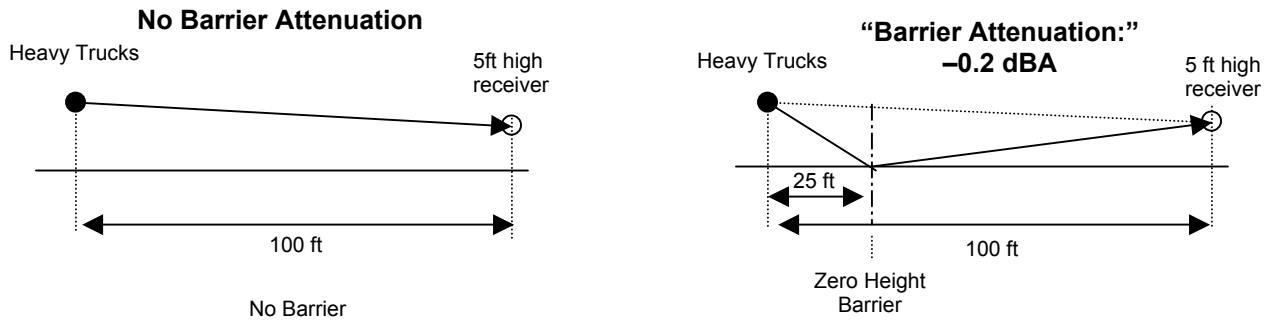
Problems. In this discussion low barriers are barriers that graze the source-to-receiver noise path or are below it. Normally, proposed noise barriers break the source-to-receiver noise paths for all vehicles and have well defined noise shadow zones, especially in simple site topographies. In complex terrain with many receivers at different elevations these shadow zones are not as obvious. Some noise paths could pass over the tops of noise barriers. Likewise, when modeling existing noise conditions, it is common practice to include existing walls and berms, or rises that are part of the existing intervening terrain between source and receiver.

According to the theory contained in FHWA-RD-77-108 (the basis for LeqV2 and Sound32 (Sound 2000), the noise along a source-to-receiver path that grazes the top of a noise barrier wall will be reduced by 5 dBA, assuming a perfect point or line source. For a noise barrier berm, however, the same situation will yield an additional 3 dBA, or total of 8 dBA barrier attenuation (see Figure 3a). For barriers below the noise path, the respective “grazing” attenuations transition to 0 dBA according to negative Fresnel Numbers, calculated from negative path length differences. The extra 3 dBA attenuation provided for berms also transitions to 0 dBA, according to an additional separate algorithm.

Figure 3b shows examples of very low barriers, resulting in negative path length differences and negative Fresnel Numbers. Because of the nature of the transition algorithms, barrier attenuation calculations in Sound32 (Sound 2000) and LeqV2 tend to over predict low-barrier attenuation. This is especially evident for barriers (walls or berms) approaching zero heights. Since those barriers are approximately the same as the no-barrier case, coding low barriers can cause significant errors. Figures 3c and 3d show differences between no barrier and zero height barrier attenuations for a receiver 100 ft from the source with and without a zero height barrier for autos and for heavy trucks. Note that the difference for heavy trucks is very small. The difference for autos, however, is significant.

Figure 3 – Low Barrier Model Predictions





d. Coding no barrier vs. coding a zero height barrier – Heavy trucks

The previously discussed hinge point problem (see *Use of Earth Berm vs. Wall Option*) shown in Figure 1c is exacerbated by the low barrier problems discussed in this section. To correctly code existing conditions for a highway on fill, the hinge point should be coded for receivers located below the hinge point elevation and, as recommended in the previous section, coded as a zero height wall. However, this may create problems when receivers are both below and above the hinge point elevation. The latter may encounter a variation of the low barrier problem, best depicted in Figure 3b.

Another thing to remember is that Sound32 (Sound2000) evaluates low barriers as follows. If a barrier is coded and the site is acoustically soft, the program first calculates the sound level at each receiver without the barrier and the soft site attenuation rate of 4.5 dBA per doubling distance (4.5 dBA/DD). Then it calculates the sound level at each receiver with the barrier with a hard site attenuation rate of 3 dBA/DD). It then keeps the situation with the greatest noise reduction for each receiver. These trade-offs may cause some inconsistencies between receivers in low barrier cases.

Coding a barrier in LeqV2 automatically overrides a soft site attenuation rate (4.5 dBA/DD) and evaluates the situation with a hard site attenuation rate (3 dBA/DD).

Recommendations. It is best to avoid low barrier problems by not coding low barriers even if they are present. However, in the case of highways on fill with receivers above and below the hinge point elevation, it is advisable to split the receivers into two groups, one consisting of receivers clearly above the hinge point and one with receivers near the hinge point elevation and below. Evaluate the former without the hinge point and the latter with the hinge point. As always there may be

exceptions. When in doubt, run the program both with and without the low barrier(s), evaluate the differences and make a judgment accordingly.

Use of the Zero Height Index

Problem. Sound32 (Sound2000) has provisions to optimize noise barriers by allowing the user to raise and lower barrier segments after the initial run. In the initial run the user declares the number of barrier height perturbations (maximum 3) up and down and the increment per perturbations. The user also codes the elevations of the bottoms (Z0) and the initial tops of the barrier segments (Z). After the initial run, the user has the option to change the barrier height index, which is based on the perturbations and increments of height. For instance, if the user declared 3 perturbations of 1 foot up and down from an initial barrier height of 10 feet, the height indices are numbered from 1 thru 7, with the middle index 4 equivalent to a height of 10 feet. Thus the barrier segment can be evaluated for other heights of 7 feet to 13 feet, in this example, by changing the initial height index of 4 to 1, 2, 3, 5, 6, or 7 with corresponding heights of 7, 8, 9, 11, 12, and 13 feet.

However, there is also a 0 height index. The purpose of the 0 height index was intended to allow the user to eliminate the barrier segment altogether. This is a useful tool to evaluate how long a barrier needs to be, by including additional end segments that can be dropped, one by one, until the noise reductions at the end receivers become too small.

In the FHWA version, this takes place in a separate program called Optima, which takes data pre-calculated in Stamina2.0 to sum up the noise contributions for each combination of barrier segment heights. In Optima, the use of the zero height index of a barrier segment is associated with the noise contribution calculated (in Stamina2.0) using the elevation of the bottom of the barrier (Z0). In a level site cross section, it will force a zero height barrier calculation as was depicted in Figures 3c and 3d with erroneous results. To avoid this problem in California versions, Sound 32 was programmed so that a zero height index would not force this calculation, but instead would ignore that segment altogether, including Z0.

By solving this problem, Sound32 created another potential problem. Suppose the barrier to be evaluated were on top of a highway cut or on top of any other existing barrier. By eliminating the segment, it would also ignore the Z0, which follows the profile of the top of the cut, i.e. the shielding provided by the top of cut would be completely ignored for the barrier segments for which the zero height index were selected. This could have especially serious consequences if the user, in trying to be more efficient, were to directly code the barrier with the Z0 or bottom of

the barrier following the profile of the top of a cut. The user might be tempted to evaluate the without barrier case by selecting zero height indices for all segments, thereby ignoring the shielding provided by the cut.

Recommendation. To avoid any zero height index problems, always remember to code in any existing barrier first (such as a top of cut), then code in the barrier to be evaluated (proposed barrier) a foot or two behind the existing barrier, with the Z0 following the profile of the top of the existing barrier. That way, when dropping a segment of the proposed barrier, the original barrier will still be accounted for. Remember that Sound32 (Sound 2000) can evaluate multiple barriers. It evaluates each one separately and keeps the best segment (i.e. the one providing the most noise reduction), and does this after each barrier segment perturbation.

Using Barrier Cost Information

Problem. After each Sound32 (Sound 2000) run, the output information consists of noise levels at each receiver and the cost of the barrier configuration selected. This cost information is different for each wall material option used (masonry, masonry on Jersey barrier, and concrete) and also for the berm option. The cost figures are derived from a data file that uses costs per lineal foot as a function of height. The file was developed from thirty 1978, '79, and '80 noise barrier projects (corrected to 1980 dollars) and is therefore entirely outdated. The purpose for the barrier costs was to allow the user to optimize their barrier designs, i.e. to offer the best noise abatement for the lowest cost.

Some users have used these costs to estimate their barrier costs. Obviously this leads to barrier cost estimates that are way below actual costs. Others have used the costs to evaluate the different material costs. Due to the outdated figures, this also leads to erroneous conclusions.

Recommendations. Do not use the cost figures for any purpose. Barrier optimization may be done by examining the best noise benefit (reduction) with the least barrier surface area. For each acoustical design. The surface areas can be obtained by summing up the areas of all the wall segments (both length and height are known) in a particular design.

Dealing with Inconsistent Results in Sound32 (Sound 2000)

Problem. Occasionally Sound32 (Sound 2000) will yield results that seem suspicious. For instance, a receiver that appears to be more exposed to highway noise has a lower predicted noise level than other

less exposed receivers. This has happened for receivers at different elevations relative to a highway hinge point (see Figure 2c). The results might show an orderly procession of increasing noise levels as their elevation increases and they transition from noise shadow zone to full exposure. Then suddenly there may be a “jump” (either up or down) in the data for a certain receiver. Frequently, these irregularities can be traced to improper coding. Occasionally there is no ready explanation for the anomaly. Most of the problems discussed thus far are common to both LeqV2 and Sound32 (Sound 2000), because they were developed from the same theory. The occasional anomaly in question, however, is peculiar to Sound32, and has to do with the programming and greater level of complexity relative to LeqV2. Sound32 does orders of magnitude more “number crunching” than LeqV2. In complex geometries the chances for the anomalies increase. LeqV2 is a much simpler program. Due to this simplicity, the results are more reliable than Sound32 (Sound 2000) results. The trade-off of course is that Sound32 can deal with more input data at once, and complex geometries.

Recommendations. When the Sound32 (Sound 2000) results at one or more receivers are suspect, the input data should be thoroughly checked. Once the user is satisfied that the input data is correct and in correct format, LeqV2 can be used to check a single receiver. The input data will probably have to be simplified. With good judgment and knowledge of what parameters are important, this can be done quickly and easily. For example, directional traffic on a tangent section can be modeled as two roadway elements in LeqV2. If the roadways are in curve, each curve may be broken into segments, the chords of which form new roadway elements. If the Sound32 file includes a barrier of various heights, these heights must be reduced to an average height. If the result of LeqV2 shows a difference, then it can be accepted that the difference is due to a glitch in Sound32 (Sound 2000).

If the inconsistency does not show up in LeqV2, the noise analyst may use the LeqV2 result. However, if the inconsistency also shows up in the LeqV2 result, it is probably due to one or more of the problem issues that we’ve discussed in this advisory, or something that we have not encountered yet. If the suspect result cannot be resolved, the best thing to do is not use it. Instead, use the results of nearby receivers. Remember; always use the best available information to make your conclusions.

Use of Grade Corrections

Problems. The grade correction algorithms in LeqV2 are different from Sound32 (Sound 2000). Both apply grade corrections only for heavy trucks going uphill. In LeqV2, the user inputs the grade correction,

while in Sound32 (Sound 2000) the grade corrections are calculated from the x, y, z lane coordinates if the user chooses grade corrections to be applied.

The grade corrections in LeqV2 are derived from an old database, and are greatly overstated. The grade corrections in Sound32 (Sound 2000) are based on the Caltrans research project that also produced the California Vehicle Noise Reference Energy Mean Emission Levels (Calveno Remels). The Sound32 (Sound 2000) grade corrections are compatible with Calveno, and are therefore superior to those in LeqV2. Results of both are significantly different.

Recommendations. Do not use the grade corrections in LeqV2. They will produce erroneous model results. The Sound32 (Sound 2000) grade corrections can be used with the following described conditions.

The grade “corrections” in Sound32 (Sound 2000) are actually not corrections to the level roadway Remels as they are in LeqV2. Instead, they are grade-dependent Remels (Calgrade) for uphill heavy trucks. They have been developed from data under the following conditions:

- 1) Heavy trucks averaging 55 mph on a level roadway, beginning a sustained grade, slowing down to a sustained “crawl speed”, which can vary widely, depending on the loads. This implies that the grade must be long enough before the uphill Remels (Calgrade) should be used. Guidance on the minimum grade length is provided in the following report: FHWA/CA/TL-87/03, titled California Vehicle Noise Emission Levels (Final Report), Office of Transportation Laboratory, Caltrans, Sacramento, CA, January 1987. The minimum grade lengths are:

- 2.0 miles for a +2% grade
- 1.7 miles for a +3% grade
- 1.4 miles for a +4% grade
- 1.2 miles for a +5% grade
- 1.0 miles for a +6% grade
- 0.8 miles for a +7% grade

Calgrade only covers data for grades from +2% to +7%.

- 2) Calgrade data were derived from observed crawl speed distributions deemed “typical” for each grade. There is a wide variety in speeds, depending on truck loading. Some truck crawl speeds are 10 mph, while others zoom by at 45 or 50 mph. The majority travel at speeds in between. No single speed can therefore be used. When a grade correction is specified, Sound32

(Sound 2000) calculates the grade, overrides any speed entered by the user and uses a composite Remel based on the typical speed distribution observed for that grade during the Calgrade research project.

The ramifications of the above are:

- Only specify grade corrections when grades are sustained, using the above guidance on minimum grade lengths. Note that Sound32 (Sound 2000) does not check whether the grade is of sufficient length. The user must determine this. Never specify grade corrections for less than the minimum distances. Trucks are still in transition from 55 mph to crawl speed in these zones. The consequences of not using grade corrections in transition zones are minimal, because the momentum of the trucks aids the trucks over short grades.
- Only specify grade corrections when heavy truck speeds before entering the grade segment are 55 mph, i.e. do not use the grade corrections if the speed limit for trucks is less than 55 mph. No data were collected for those conditions. If the speed limit is 55 mph, it can safely be assumed that trucks will at least go that fast.